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(19) (CA) **CANADIAN PATENT** (12)

(54) PATTERN DENSIFIED FIBROUS WEB HAVING SPACED, BINDER  
IMPREGNATED HIGH DENSITY ZONES, AND METHOD OF MAKING  
SUCH A WEB

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PATTERN DENSIFIED FIBROUS WEB  
HAVING SPACED, BINDER IMPREGNATED HIGH  
DENSITY ZONES, AND METHOD OF MAKING SUCH A WEB

ABSTRACT

A soft, pattern densified fibrous web such as a paper sheet which web generally comprises a relatively low bond, high bulk, vaulted field and a patterned array of spaced zones of relatively high fiber density, at least a substantial proportion of which dense zones are at least partially impregnated with binder material; and method of making such a web. The method generally entails forming a low bond, pattern densified fibrous web; supporting dense zones of the web on a patterned array of spaced supports; displacing the unsupported portions of the web into the spaces intermediate the spaced supports; and applying a binder material to dense supported zones of the web. For instance, such a web may be made by: forming a pattern densified embryonic web from an aqueous slurry of low bond fibers; supporting dense zones of the embryonic web on outwardly facing knuckles of an imprinting carrier fabric and subjecting it to a differential pressure to effect displacing unsupported portions thereof out of the top-surface-plane of the knuckles and into the interfilamentary spaces of the carrier fabric; predrying the embryonic web to a fiber consistency of from about 30 to about 95 percent or more, preferably from about 60 to about 90 percent; gravure impregnating dense supported zones of the predried web with binder material; and finally drying the web. The degree of impregnating and bonding in the dense zones may be increased by applying mechanical compression to the impregnated zones subsequent to applying the binder material. The web may also be creped to increase its stretch and bulk, and to increase its softness by disrupting some of the interfilamentary bonds within the web.

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Claims

1. A pattern densified fibrous web comprising a relatively high bulk field having a relatively low fiber density, and a patterned array of spaced discrete zones of relatively high fiber density integrated with said relatively high bulk field, said high bulk field comprising a multiplicity of arched spans which corporately coact with said high density zones to provide said web with a vaulted character, and at least a substantial proportion of said high density zones being at least partially impregnated with inter-fiber binder material through the full thickness of said web, and said high bulk field being substantially devoid of said binder material.
2. The pattern densified fibrous web of Claim 1 wherein said high density zones have a corporate surface area which constitutes from about 10 to about 50 percent of the total surface area of said web, and wherein the portions of said zones which are impregnated with said binder material underlie from about 25 to about 75 percent of the corporate surface area of said zones.
3. The pattern densified fibrous web of Claim 1 wherein said high density zones have a corporate surface area which constitutes from about 20 to about 40 percent of the total surface area of said web, and wherein the portions of said zones which are impregnated with said binder material underlie from about 25 to about 75 percent of the corporate surface area of said zones.
4. The pattern densified fibrous web of Claim 2 or 3 wherein the portions of said zones which are impregnated with said binding material underlie about 50 percent of the corporate surface area of said zones.
5. The pattern densified fibrous web of Claim 1, 2, or 3 comprising a principal web-strength fiber constituent comprising fibers of sufficient average length with respect to the spacing of impregnated high density zones that a substantial fraction of said fibers will have spaced portions thereof disposed in adjacent impregnated high density zones and in overlapping bonded relation with portions of other fibers so that said fibers constitute a strength-skeletal-network of said web.
6. The pattern densified fibrous web of Claim 1, 2, or 3 comprising a principal web-strength fiber constituent wherein the fibers constituting said principal fiber constituent are relatively long papermaking fibers having average lengths of about 2.0 mm or more.

7. The pattern densified fibrous web of Claim 1, 2, or 3 comprising a principal web-strength fiber constituent wherein the fibers constituting said principal fiber constituent are papermaking fibers and said web further comprises means for providing a relatively low degree of interfiber hydrogen bonding.

8. The pattern densified fibrous web of Claim 1, 2, or 3 comprising a principal web-strength fiber constituent wherein the fibers constituting said principal fiber constituent are papermaking fibers and said web further comprises sufficient fiber-debonding material which is so disposed to obviate a high degree of interfiber hydrogen bonding intermediate papermaking fibers.

9. The pattern densified fibrous web of Claim 1, 2, or 3 comprising a principal web-strength fiber constituent wherein the fibers constituting said principal fiber constituent are papermaking fibers and comprise papermaking fibers having a relatively low inherent interfiber hydrogen bonding propensity.

10. A method of making a pattern densified, partially impregnated fibrous web comprising a multiplicity of discrete zones of relatively high fiber density in which web at least a substantial proportion of said zones are at least partially impregnated with a non-fibrous impregnating material, said method comprising the steps of

forming a fibrous, pattern densified embryonic web having a multiplicity of discrete zones of relatively high fiber density which zones are disposed in a predetermined patterned array,  
supporting said embryonic web on an array of spaced supports so that each of a predetermined sub-array of said zones is juxtaposed one of a predetermined sub-array of said supports, and  
at least partially impregnating at least a substantial portion of the supported predetermined sub-array of said zones with an impregnating material by biasing said predetermined sub-array of said supports towards a contacting type impregnating means with said sub-array of said zones disposed between said sub-array of said supports and said impregnating means.

11. The method of Claim 10 wherein said forming step comprises depositing an aqueous fibrous slurry onto a forming member and removing sufficient water therefrom to effect formation of an embryonic fibrous web, and said method further comprises the step of completing the drying of said embryonic web after said impregnating.
12. The method of Claim 10 or 11 wherein said supports are integrated into a loop of an imprinting carrier fabric having outwardly facing knuckles which knuckles are designated said supports, said fabrics having meshes of from about 4-MD/4-CD to about 24-MD/24-CD filaments per centimeter.
13. The method of Claim 10 or 11 wherein said supports are integrated into a loop of an imprinting carrier fabric having outwardly facing knuckles which knuckles are designated said supports, said fabrics having meshes of from about 8-MD/8-CD to about 20-MD/20-CD filaments per centimeter.
14. The method of Claim 10 or 11 wherein said web comprises a principal web-strength fiber constituent of fibers of sufficient average length with respect to the spacing of said supports constituting said predetermined sub-array of said supports that after said web is formed a substantial fraction of said fibers will have spaced portions thereof disposed on adjacent supports of said sub-array of said supports and in overlapping relation with portions of other fibers whereby said fibers constitute a strength-skeletal-network of said web with said overlapping portions of said fibers bonded together.
15. The method of Claim 10 or 11 wherein said impregnating material comprises a binder material.
16. The method of Claim 11 wherein said impregnating material comprises binder material and said aqueous fibrous slurry comprises a fibrous furnish of sufficiently low inherent interfiber bonding propensity that said embryonic fibrous web would have insufficient integral structural integrity to be self supporting while being impregnated with said binder material.

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17. The method of Claim 11 further comprising the step of drying of said embryonic web in the absence of substantial mechanical compression to an average fiber consistency of from about 30 to about 95 percent prior to said impregnating.
18. The method of Claim 17 wherein said drying is conducted until said embryonic web has an average fiber consistency of from about 60 to about 90 percent prior to said impregnating.
19. The method of Claim 17 wherein said drying is effected in such a manner that the unsupported spans of said embryonic web are dried substantially more than the supported zones of said embryonic web.
20. The method of Claim 19 wherein said drying is effected by blow through drying means while said web is supported on said supports.
21. The method of Claim 10, 11 or 17, further comprising the step of sufficiently deflecting the spans of said embryonic web disposed intermediate said spaced supports into the spaces disposed intermediate said supports to substantially obviate impregnating said spans when said sub-array of said supports is biased towards said impregnating means.
22. The method of Claim 10, 11 or 17 further comprising the step of sufficiently deflecting the spans of said embryonic web disposed intermediate said supports into the spaces disposed intermediate said supports to substantially obviate impregnating said spans when said sub-array of said supports is biased towards said impregnating means wherein said deflecting is effected by applying a differential fluid pressure across said supported web.
23. The method of Claim 10, 11 or 17 further comprising the step of subjecting said supported zones to substantial mechanical compression after said impregnating has been effected.

24. The method of Claim 10, 11 or 17 further comprising the step of subjecting said supported zones substantial mechanical compression after said impregnating has been effected and further comprising the step of sufficiently deflecting the spans of said embryonic web disposed intermediate said spaced supports into the spaces disposed intermediate said supports to substantially obviate impregnating said spans when said sub-array of said supports is biased towards said impregnating means.

25. The method of Claim 10, 11 or 17 wherein said predetermined sub-array of said supports coacts with an impregnation pattern of said impregnating means so that said impregnating material is applied to only the portions of said zones disposed intermediate registered areas of said predetermined sub-array of said supports and said impregnating pattern during said impregnating.

26. The method of Claim 10, 11 or 17 wherein said predetermined sub-array of said supports coacts with an impregnation pattern of said impregnating means so that said impregnating material is applied to only the portions of said zones disposed intermediate registered areas of said predetermined sub-array of said supports and said impregnating pattern during said impregnating which further comprises the step of sufficiently deflecting the spans of said embryonic web disposed intermediate said spaced supports into the spaces disposed intermediate said supports to substantially obviate impregnating said spans when said sub-array of said supports is biased towards said impregnating means.

27. The method of Claim 10, 11 or 17 wherein said predetermined sub-array of said supports coacts with an impregnation pattern of said impregnating means so that said impregnating material is applied to only the portions of said zones disposed intermediate registered areas of said predetermined sub-array of said supports and said impregnating pattern during said impregnating which comprises the step of subjecting said supported zones to substantial mechanical compression after said impregnating has been effected.

28. The method of Claim 10,11 or 17 wherein said predetermined sub-array of said supports coacts with an impregnation pattern of said impregnating means so that said impregnating material is applied to only the portions of said zones disposed intermediate registered areas of said predetermined sub-array of said supports and said impregnating pattern during said impregnating which comprises the step of subjecting said supported zones to substantial mechanical compression after said impregnating has been effected which further comprises the step of sufficiently deflecting the spans of said embryonic web disposed intermediate said spaced supports into the spaces disposed intermediate said supports to substantially obviates impregnating said spans when said sub-array of said supports is biased towards said impregnating means.



PATTERN DENSIFIED FIBROUS WEB  
HAVING SPACED, BINDER IMPREGNATED HIGH  
DENSITY ZONES, AND METHOD OF MAKING SUCH A WEB

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John Michael Raley

Technical Field

This invention relates to soft fibrous webs such as paper for paper towels and tissue paper, and a method of making such a web which is reinforced at least in part by 5 binder material.

Background Art

In general, the exemplary patents described below disclose soft, relatively high bulk webs such as paper, and concomitant processes, some of which include pattern applied 10 binder materials such as elastomers for the purpose of strengthening the fibrous webs without making them inordinately inflexible or hard or harsh to feel.

U.S. Patent No. 2,039,312 which issued May 5, 1936 to J. H. Goldman discloses a Reinforced Carded Web which may be 15 reinforced by a reticulated network of narrow lines of impregnation with a suitable binder which lines are preferably spaced slightly less than the average fiber length of the fibers constituting the web.

U.S. Patents No. 2,880,111 and No. 3,009,822 which 20 issued to A. H. Drelich et al. on March 31, 1959 and November 21, 1961, respectively, disclose fibrous Textile-Like Nonwoven Fabrics wherein the fibers are held together by an adhesive or bonding material distributed amongst them in predetermined patterns of closely spaced discrete areas. 25 The latter patent also discloses lined patterns of binder as well as a rotogravure method of making such fabrics which

includes the step of wetting a fibrous web prior to rotogravure printing a predetermined pattern of spaced binder segments.

U.S. Patent No. 3,301,746 which issued January 31, 1967 to Lawrence H. Sanford and James B. Sisson covers a Process 5 For Forming Absorbent Paper By Imprinting A Fabric Knuckle Pattern Thereon Prior To Drying And Process Thereof. Briefly, a high bulk fibrous web is wet formed and predried to a fiber consistency of from about 30 to about 80 percent by avoiding substantial mechanical compression until the web is 10 predried; then a knuckle pattern of an imprinting fabric is imprinted in the predried web while the remainder remains substantially uncompacted. The web may also be somewhat molded to the surface of the imprinting fabric by differential fluid forces prior to the predrying. Upon being imprinted, 15 the imprinted zones become compacted and relatively highly hydrogen bonded due to the imprinting pressure and the water remaining in the predried web prior to final drying. Thus, upon final drying, the resulting paper is pattern compacted and bonded in the image of the knuckle pattern of the imprinting fabric. It is believed that such paper is soft 20 and bulky because of not being compacted overall and because the fibers disposed in the uncompacted portions do not become highly hydrogen bonded as in theretofore conventional felt-pressing papermaking. U.S. Patent No. 3,994,771 which 25 issued November 30, 1976 to George Morgan, Jr., et al. extended this technology to a Process For Forming A Layered Paper Web Having Improved Bulk, Tactile Impression And Absorbency And Paper Thereof.

U.S. Patent No. 4,158,594 which was filed June 24, 1971 30 and issued June 19, 1979 to Henry E. Becker et al. discloses Bonded, Differentially Creped, Fibrous Webs And Method of Making Same wherein creping bonding material such as latex is pattern gravure printed onto a dried, self-supporting fibrous web having relatively low interfiber bonding strength. 35 The web is preferably creped prior to printing, and is printed while being forwarded onto a creping cylinder from which it is subsequently differentially creped. This

patent recites that it is particularly desirable to apply the bonding material in a reticular pattern so that the bonding material forms a net-like web of strength over the fibrous web. Indeed, all of the disclosed examples were 5 printed with a reticular pattern although both discrete spot bonding and reticular pattern bonding are shown in the figures. This technology was apparently broadened somewhat by the following commonly assigned patents although all commonly show gravure printing of bonding material onto 10 dried, self-supporting fibrous webs: U.S. Patents No. 3,879,257 which issued April 22, 1975; No. 3,903,342 which issued September 2, 1975; and No. 4,000,237 which issued December 28, 1976.

U.S. Patent No. 3,812,000 which issued May 21, 1974 to 15 J.L. Salvucci et al. discloses a Soft, Absorbent, Fibrous, Sheet Material Formed By Avoiding Mechanical Compression Of The Elastomer Containing Fiber Furnish Until The Sheet Is At Least 80% Dry. As disclosed, an elastomeric bonding material is included in the fiber furnish so that it is distributed 20 throughout the finished sheet. Additionally, more such bonding material may be applied to the sheet in a predetermined pattern by a patterned gravure roll while the sheet is being forwarded through a paper machine on a foraminous drying fabric. The pattern is stated to preferably be a reticular hexagonal pattern. As compared to the Sanford-Sisson patent 25 described above, Salvucci et al. include elastomeric material in a low-bond furnish; predry to a greater extent; and may gravure print a pattern of additional binder material on the web with a patterned gravure roll. However, Salvucci et al. 30 expressly teach away from pattern knuckle compaction as taught by Sanford-Sisson because "the pressures generated by the knuckle pattern of the woven wire are so high as to create hard portions of the web which give a feeling of harshness to the resulting product."

35 U.S. Patent No. 3,898,123 which issued August 5, 1975 to Charles H. Phillips et al. discloses a Method For Wet Print-Bonding Light-Weight Wet-Formed Fibrous Webs wherein a

self-supporting, wet-formed web has an aqueous resin binder applied by print-bonding rolls having etched or engraved printing surfaces, and which binder material is applied intermediate two open draw free spans of the web prior to 5 drying the web.

U.S. Patent No. 4,127,637 which issued November 28, 1978 to Eugene J. Pietreniak et al. discloses a Method Of Manufacturing A Dry-Formed, Embossed Adhesively Bonded, Nonwoven Fibrous Sheet having spaced uncompacted fibrous 10 zones on a compacted reticulated fibrous network wherein binder material is preferably disposed in the uncompacted zones and through the compacted network.

U.S. Patent No. 4,159,355 which issued June 26, 1979 to Kenneth Kaufman discloses Foam Bonding method and apparatus 15 for applying a foamed binder in a uniform and controlled metered flow to a surface of a moving substrate such as a nonwoven web.

Additionally, a paper titled Forming Of Low Density Nonwoven Fabrics: Technology And Direction was presented by 20 G.A.M. Butterworth on November 13, 1979 at the International Air Laid And Low Density Forming Seminar at the Hyatt Regency Hotel in Atlanta, Georgia. This paper provides a consolidated discussion of patents pertaining to low density webs including webs which are at least partially impregnated with, for 25 instance, binder material.

While not intending to limit the present invention to the following generalized distinctions, the present invention provides, as compared to the foregoing background art, a generally relatively low bond, high bulk, highly flexible 30 pattern densified web such as a paper sheet having spaced discrete zones of relatively high fiber density which zones are sufficiently impregnated with binder material to provide adequate sheet tensile strength without compacting or impregnating the surrounding low density portions of the web; and the 35 present invention provides a concomitant method of making

such a web. That is, the background art does not disclose applying binder material to only relatively dense zones of a fibrous web having a patterned array of spaced discrete high fiber density zones as provided by the present invention.

. 5 Disclosure Of The Invention

In accordance with one broad aspect of the present invention there is provided a pattern densified fibrous web and concomitant method of making such a web which web has a relatively high bulk field of relatively low fiber density, 10 and a patterned array of spaced zones of relatively high fiber density at least a substantial proportion of which zones are at least partially impregnated with binder material, and in which web the high bulk field is substantially uncompacted and devoid of such binder material. The con- 15 comitant method comprises the steps of forming a pattern densified embryonic web having an array of discrete high density zones disposed in a predetermined pattern; supporting the embryonic web on a corresponding array of spaced supports so that at least each of a predetermined sub-array of the 20 dense zones is juxtaposed one of a corresponding sub-array of the supports; and biasing the sub-array of supports towards a contacting type impregnating means with the sub- array of dense zones disposed therebetween so that, through coincidence of at least a substantial number of the supports 25 of the sub-array and binder transfer portions of the impregnating means, at least a substantial proportion of the dense zones become at least partially impregnated. In the method, the array of spaced supports may be the knuckles of an endless imprinting carrier fabric and the sub-array of 30 such supports may be only the top-surface-plane knuckles of the fabric in fabrics having both top-surface-plane knuckles and sub-top-surface knuckles. In fabrics having no sub-top- surface knuckles the sub-array of supports would in fact be the array of supports. For maximum strength, all of the 35 high density zones are impregnated with binder material whereas only some may only be partially impregnated in sheets wherein partial impregnation provides sufficient sheet strength for the intended use of the sheets.

Impregnating means such as a full field gravure applicator may be used to impregnate the dense zones of the web biased against it whereas less-than-full-field gravure applicators may be used to only partially impregnate all or some of the dense zones of the web, or wholly impregnate only some of the dense zones. Moreover, the method may further comprise the step of subjecting the impregnated zones to further mechanical pressure/compaction after they are impregnated to increase the binder penetration and interfiber bonding therein.

More particularly, the present invention, in its product aspect, resides in a pattern densified fibrous web comprising a relatively high bulk field having a relatively low fiber density, and a patterned array of spaced discrete zones of relatively high fiber density integrated with said relatively high bulk field, said high bulk field comprising a multiplicity of arched spans which corporately coact with said high density zones to provide said web with a vaulted, character, and at least a substantial proportion of said high density zones being at least partially impregnated with inter-fiber binder material through the full thickness of said web, and said high bulk field being substantially devoid of said binder material.

Brief Description of the Drawings

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter regarded as forming the present invention, it is believed the invention will be better understood from the following description taken in conjunction with the accompanying drawings in which corresponding features are identically designated, and in which:

Figure 1 is an enlarged photographic sectional view of a fragmentary sheet of paper embodying the present invention.

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Figure 2 is a fragmentary plan view drawing of a sheet of paper embodying the present invention which sheet comprises a predetermined pattern of spaced high density zones disposed on a relatively high bulk field.

Figure 3 is a fragmentary sectional view drawing of a sheet of paper embodying the present invention which sectional view is taken along line 3-3 of Figure 2, and which sectional view generally corresponds to the photographic sectional view of Figure 1.

Figure 4 is a fragmentary sectional view drawing of a sheet of paper which is substantially identical to that shown in Figure 3 except the flat, high density zones of the Figure 4 sheet are not impregnated with binder material.

Figure 5 is a side elevational, somewhat schematic view of a papermaking machine for manufacturing a wet laid fibrous web such as paper in accordance with the present invention.

Figure 6 is a fragmentary plan view of an exemplary 5 imprinting carrier fabric such as may be used on the papermaking machine shown in Figure 5 and which imprints its top-surface-plane knuckle pattern into a web such as a sheet of paper to precipitate a pattern of compacted zones.

Figure 7 is a radially inwardly looking, fragmentary 10 view of the surface of a rotogravure cylinder having a full field of truncated pyramidal reservoirs formed therein, and having a partially peeled back opaque overlay disposed thereon which overlay is apertured in the knuckle pattern of the imprinting carrier fabric shown in Figure 6.

15 Figures 8 through 12 are partially masked fragmentary rotogravure cylinders which are substantially identical to that shown in Figure 7 except the cylinders of Figures 8 through 12 are less-than-full-field micropatterned to provide reservoirs over only about 75, 50, 50, 50, and 25 percent, 20 respectively, of their cylindrical surface areas.

Figure 13 is a somewhat schematic side elevational view of a handsheet impregnating apparatus.

Figure 14 is an enlarged scale, fragmentary view of the roller-nip portion of the apparatus shown in Figure 13 and 25 through which nip portion a handsheet disposed on an imprinting carrier fabric, and a flat gravure plate are being forwarded in juxtaposed relation.

Figure 15 is an enlarged scale, fragmentary view similar to Figure 14 except the handsheet of Figure 15 is not disposed 30 on an imprinting carrier fabric as shown in Figure 14.

Detailed Description Of The Invention

A fragmentary portion of a microtomed section of a paper sheet embodying the present invention is shown in the photographic Figure 1 to comprise a fibrous web 20 comprising a multiplicity of fibers 21 which are disposed in relatively high density zones 22 and 23, and arcuate-shape relatively low density span portions 24, and in which web the high density zones 22 and 23 are impregnated with a latex fiber binder material 25.

Briefly, as described more fully hereinafter in conjunction with discussing web 20, Figures 2, 3 and 4, the present invention provides a soft, pattern densified fibrous web such as a paper sheet which comprises a relatively low density fibrous field and a multiplicity of relatively high density fibrous zones disposed in a predetermined array, and in which web each of at least a substantial proportion of such dense zones are at least partially impregnated with a binder material of a type which provides interfiber bonds which are preferably substantially more flexible than ordinary interfiber hydrogen bonds which occur between cellulosic fibers in ordinary papermaking. The web comprises a principal web-strength fiber constituent comprising fibers of sufficient average length with respect to the spacing of the impregnated high density zones that a substantial fraction of the fibers will have spaced portions thereof disposed in adjacent impregnated dense zones and in overlapping bonded relation with portions of other fibers so that the bonded principal web-strength fibers constitute a strength-skeletal-network of the web. Preferably, the low density field comprises arcuate-shape spans which are so disposed with respect to the dense zones that the web has a vaulted character. Also, preferably: the principal web-strength fibers have average lengths of about 2.0 mm or greater (e.g., softwood fibers); but for the impregnated dense zones, the web is characterized by a relatively low degree of interfiber bonding which may be achieved by including debonders in the furnish, or through the use of low bond fibers; and the dense zones preferably

are equal in number to the number of imprinting knuckles of an imprinting fabric having a mesh count of from about 10-MD/10-CD to about 60-MD/60-CD filaments per inch (from about 4 by 4 to about 24 by 24 machine direction filaments and 5 cross machine direction filaments per centimeter, respectively) and more preferably from about 20-MD/20-CD to about 50-MD/50-CD filaments per inch (from about 8 by 8 to about 20 by 20 machine direction filaments and cross machine direction filaments per centimeter, respectively).

10 Briefly, a web embodiment of the present invention as described above is preferably made by forming a pattern densified web of fibers of appropriate lengths, flexibility, and bonding propensity; supporting high density zones of the web on an array of spaced supports which are preferably 15 generally coplanar; deflecting the webs low density span portions out of the plane of the supports; and impregnating at least a substantial proportion of the dense zones. The degree of impregnation and/or bonding may be increased by subjecting the high density zones to mechanical compression 20 after the basic impregnation has been effected. For instance, a wet formed embryonic web may be so pattern densified and deflected by a differential fluid pressure while the embryonic web is disposed on an appropriate imprinting carrier fabric as described hereinafter in conjunction with discussing 25 Figure 6; and the impregnating may be effected, for instance, by a pressure biased gravure apparatus as also described hereinafter. Preferably, the web is also creped, calendered and reeled after being impregnated and dried to further increase its stretch, bulk and softness, and to control its 30 caliper.

Referring again to Figure 1, web 20 and the preferred process for making it in accordance with the present invention are described hereinafter as paper sheet 20 and papermaking processes, respectively, although it is not intended to 35 thereby limit the present invention.

Figure 3 is a fragmentary sectional view drawing of a paper sheet 20 embodying the present invention which view is taken along line 3-3 of Figure 2, and which sectional view drawing generally corresponds to the photographic sectional view of Figure 1. That is, paper sheet 20 is shown in Figure 3 to comprise arcuate-shape low density span portions 24 which are alternately spaced by relatively long and short high density zones 22 and 23, respectively, which dense zones are generally planar and are impregnated with binder material 25. As may be seen in Figure 2, a multiplicity of dense zones 22 and 23 are disposed in a predetermined pattern or array on a generally low density field of which portions 24, Figure 3, are representative.

Figure 4 is a fragmentary sectional view drawing of a pattern densified paper sheet 20a which generally corresponds with paper sheet 20, Figure 3, except paper sheet 20a is not impregnated with binder material. That is, paper sheet 20a is a pattern densified web which has not had its high density zones impregnated with binder material in accordance with the present invention. Also, the relative fiber density of zones 22a and 23a of unimpregnated sheet 20a is shown to be somewhat less than the fiber density of zones 22 and 23 of sheet 20 because zones 22a and 23a have not been subjected to the mechanical compaction experienced by zones 22 and 23 through the practice of the present invention as hereinbefore described.

Figure 5 is a fragmentary, somewhat schematic side elevational view of an exemplary papermaking machine 30 through the use of which paper sheet embodiments of the present invention can be made and the process of the present invention can be practiced. Papermaking machine 30 is a fixed roof former type papermaking machine wherein a fibrous slurry is delivered from a headbox 32 onto a Fourdrinier wire 33 passing over a vacuum type breast roll 34. The Fourdrinier wire then passes over a forming board 35 and suction box 36 and is further looped about turning rolls 41 through 46. The slurry is partially dewatered by the vacuum

and table roll action of the breast roll. Further dewatering is precipitated by forming board 35 and suction box 36 so that an embryonic fibrous web 20e is formed and forwarded on the Fourdrinier wire to a first transfer station generally 5 designated 50 where it is transferred from Fourdrinier wire 33 to an endless intermediate carrier fabric 51 which partially wraps roll 42, passes over suction boxes 52 and 53, then over vacuum transfer box 54, and then is looped about rolls 55, 56, 57 and 58. Dewatering is furthered as 10 the embryonic web 20e is forwarded in sandwiched relation between Fourdrinier wire 33 and fabric 51 past suction boxes 52 and 53, and then over a portion of vacuum transfer box 54 after which the embryonic web 20e is disposed and forwarded on fabric 51 to an endless imprinting carrier fabric 59 at a 15 second transfer station designated 60. At the second transfer station 60, embryonic web 20e is transferred by the action of vacuum transfer box 61 from the intermediate carrier fabric 51 to the imprinting carrier fabric 59 which is looped past/about suction box 62, turning roll 63, blow 20 through predryer 64, impregnating means 65, turning roll 66, pressure roll 67, turning roll 68, showers 69, suction box 70, and turning rolls 71 and 72. At this time, formation of the web continues due to the differential fluid pressure applied to the web to effect the second transfer and fiber 25 mobility enabled by a sufficiently high water content (preferably a fiber consistency of 30 percent or less), the embryonic web becomes pattern densified with dense zones of fibers juxtaposed the knuckles of the imprinting carrier fabric 59. After being transferred to the imprinting carrier 30 fabric 59, the embryonic web is further dewatered by suction box 62 and blow through predryer 64; then partially impregnated with binder material 25 by pressure biased impregnating means 65; and then transferred to Yankee dryer 75 by the action of pressure roll 67 which is biased towards the 35 Yankee dryer by biasing means 76. Transfer of the web to the Yankee dryer and adherence thereto is enabled by creping adhesive applied through applicator 77. Finally, upon being fully dried on the Yankee dryer, the transformation of

embryonic web 20e to paper sheet 20 is completed as the final drying thereof is effected and, preferably, it is creped from the Yankee dryer by the action of doctor blade 78. Preferably, the paper sheet 20 is then calendered and 5 reeled to control its caliper and enable its subsequent conversion from reels into paper products such as paper towels, and toilet and facial tissue paper. Also, in the event the binder material requires curing, such curing may be effected at least in part after the paper sheet has been 10 removed from the papermaking machine.

Figure 6 is a plan view of the top, outwardly facing surface of an exemplary imprinting carrier fabric 59 which may be used on a papermaking machine such as papermaking machine 30, Figure 5, to practice the present invention. 15 Fabric 59 is a five-shed satin weave of polyester monofilaments which were woven using a 1, 4, 2, 5, 3 warp pick sequence and wherein the filaments 90-1 through 90-5 which extend in the machine direction, MD, alternately pass over four and under one of the filaments 91-1 through 91-5 which extend in 20 the cross machine direction, CD; and wherein the CD filaments alternately pass over one and under four MD filaments. Fabric 59 has been stressed, heat set, and sanded to provide coplanar sets of long MD imprinting knuckles 92, and relatively short 1-over CD imprinting knuckles 93. The outwardly 25 facing surfaces of coplanar sets of knuckles 92 and 93 corporately define a top-surface-plane of fabric 59. Fabric 59 also has adjacent pairs of sub-top-surface filament crossovers designated 94 which, by virtue of the weave, stressing, and heat setting are recessed below the top-surface-plane of the fabric. Such a fabric is described more fully in the commonly assigned U.S. Patent No. 4,239,065 of Paul Dennis Trohan, granted December 16, 1980. Also, such a fabric is particularly useful 35 for making soft and absorbent imprinted paper having uncompressed portions circumscribed by picket-like lineaments of alternatiely spaced areas of compacted fibers and non-compacted fibers which compacted fiber areas or zones are

precipitated by imprinting the top-surface-plane knuckles of the fabric into a relatively uncompacted, low density, high bulk paper sheet. This is more fully described in the commonly assigned U.S. Patent No. 4,191,609 of Paul

5 Dennis Trokhan, issued March 4, 1980. While the 5-shed fabric 59, Figure 5, has been described above as exemplary with respect to the present invention it is not intended to thereby limit the present invention to any particular fabric weave, or knuckle geometry or disposition.

10 Impregnating means 65, Figure 5, comprises rotogravure cylinder 81, backing roll 82, biasing means 83, and reservoir 85 which is adapted by means not shown to maintain a relatively constant predetermined level of liquid impregnating material 25 therein. This level insures that a downwardly 15 facing arcuate portion of rotogravure cylinder 81 is immersed in the impregnating material. Doctor means, not shown, are provided for removing the excess impregnating material from the rotogravure cylinder as it rotates upwardly towards the traveling embryonic web. Synchronous drive means, not 20 shown, may also be provided as needed to obviate deleterious drag on the embryonic web as it passes through the nip between rotogravure cylinder 81 and backing roll 82. While, as described, impregnating means 65 of papermaking machine 30 is a gravure type applicator, it is not intended to thereby 25 limit the present invention to gravure applicators or impregnators. Rather, it is believed that other contacting type applicators such as, for instance, foam applicators may be used to practice the present invention.

30 Figure 7 is an enlarged scale, radially inwardly looking view of a fragmentary portion of an exemplary rotogravure cylinder 81 which has its cylindrical surface covered by a partially peeled back, opaque mask 96 which is apertured in the top-surface-plane knuckle pattern of imprinting carrier fabric 59, Figure 6. That is, apertures 92a and 93a in mask

96 are sized and disposed in the image of the top-surface-plane knuckle pattern of fabric 59, Figure 6. The entire gravure surface of rotogravure cylinder 81 is defined by a full field pattern of truncated pyramidal cavities or

5 reservoirs 100. In use, as an embryonic web 20e is carried through the nip of impregnating means 65 of papermaking machine 30, Figure 4, only the dense zones of the web which are juxtaposed top-surface-plane knuckles 92 and 93 of fabric 59 are biased against the rotogravure cylinder 81.

10 This substantially limits the pattern of impregnation to the pattern of the high density zones juxtaposed the top-surface-plane knuckles 92 and 93 of fabric 59. Thus, the pattern of impregnation is determined by the patterned array of top-surface-plane knuckles of the imprinting carrier fabric

15 rather than a pattern on the rotogravure cylinder. Also, the pattern of impregnation of the web is in registration with the pattern of dense zones of the web as illustrated in web 20, Figures 1 and 3. However, the area of the web which becomes impregnated may in fact be substantially larger than

20 the sanded areas of knuckles 92 and 93 because the filaments of the woven fabric 59 gradually slope away from the sanded areas of the knuckles and thus cause web portions contiguous thereto to be impregnated along with the web portions immediately juxtaposed the sanded areas of the knuckles.

25 Furthermore, it is believed that the absence of biasing of the unsupported span portions of the embryonic web substantially obviates transfer of binding material thereto from rotogravure cylinder 81. Moreover, displacement of the unsupported span portions into the interfilamentary spaces of the imprinting

30 fabric may be effected to virtually totally obviate their being impregnated by rotogravure cylinder 81.

Figures 8 through 12 are similar to Figure 7 except the alternate embodiment rotogravure cylinders 81a through 81e of Figures 8 through 12, respectively, are provided with

35 less-than-full-field checkerboard type patterns of reservoirs 100 which reservoirs cover 75, 50, 50, 50, and 25 percent, respectively, of the working surfaces of cylinders 81a, 81b, 81c, 81d, and 81e. Thus, such less-than-full-field patterned

rotogravure cylinders will coact with a patterned imprinting fabric to apply impregnating material to only the surface portions of an embryonic web which are in registered relation with top-surface-plane knuckles and adjacent reservoir 5 portions of the rotogravure cylinder pattern. Such patterned cylinders are useful with respect to providing various degrees of web strength through binder impregnation while preserving various complementary degrees of binder free surface areas. Thus, strength may be increased by impregnating 10 larger percentages of web surface area. Furthermore, whereas the alternate embodiment, less-than-full-field, rotogravure cylinders 81a through 81e have relatively small checkerboard-type patterns with respect to the knuckle pattern of fabric 59, Figure 6, less-than-full-field patterns (not shown) having 15 larger open (non-printing/non-impregnating) areas may be used to assure not impregnating a substantial proportion of the dense zones as well as concurrently assuring that a substantial proportion of the dense zones will be impregnated. This is useful when, for instance, creping of the finished web is 20 desired and the binder substantially vitiates the intended function of a creping adhesive (e.g.: polyvinyl alcohol applied by spray applicators 77, Figure 5), the proportion of binder impregnated zones is maintained great enough to provide adequate web strength while the proportion of 25 non-binder-impregnated zones is made great enough to enable the creping adhesive to securely affix those zones to the Yankee dryer (creping cylinder) to control the web and the creping thereof in substantially the manner disclosed in the hereinbefore referenced Sanford-Sisson patent (U.S. Patent No. 3,301,746).

30. Figure 13 is a somewhat schematic side elevational view of a handsheet impregnating apparatus 106 which comprises rotatably mounted, rubber covered rolls 107 and 108, a slanted feed plate 109, a horizontal feed plate 110, and a receiving plate 111. Means not shown are provided to pressure 35 bias rolls 107 and 108 together, and to synchronously rotate rolls 107 and 108 in the directions indicated by the arrows drawn thereon.

Figure 14 is a fragmentary enlarged scale view of the nip portion of apparatus 106, Figure 13, which view shows fragmentary sections of rolls 107 and 108, a gravure plate 115, and a paper handsheet 116 disposed on the under side of 5 an imprinting carrier fabric 117. Figure 15 is substantially identical to Figure 14 except the handsheet 116 in Figure 15 is self-supported; i.e., not disposed on an imprinting carrier fabric.

In use, referring to handsheet impregnating apparatus 106, Figures 13 through 15, a gravure plate 115 is placed on plate 110 with its pattern side up and with its cells filled with binder material. Then, a handsheet 116 is placed on plate 109. Handsheet 116 may be associated with an imprinting carrier fabric 117 as indicated in Figure 14, or not so 15 associated as indicated by the absence of such a fabric 117 from Figure 15. Then, rolls 107 and 108 are biased together with a predetermined force and rotated synchronously while the handsheet 116 and the gravure plate 115 are simultaneously moved so that their leading edges enter the nip between the 20 rolls. Thus, as the handsheet and gravure plate pass through the nip, the handsheet becomes impregnated. When the web is associated with a fabric during impregnation as shown in Figure 14, the pattern of web impregnation is the knuckle pattern of the fabric when a full field gravure plate is 25 used. Therefore, when the handsheet has been pattern densified by formation on an imprinting carrier fabric so that the dense zones of the handsheet are juxtaposed the knuckles of the imprinting carrier fabric, only the dense zones of the handsheet become impregnated by a full field 30 gravure plate through the use of handsheet impregnating apparatus 106.

Briefly, referring back to Figure 5, an embryonic web 20e is preferably formed and forwarded without subjecting it to substantial mechanical compaction until it reaches the 35 impregnating means 65. By including a principal web-strength fiber constituent in the furnish which constituent consists of fibers having a predetermined average length relation with respect

to the knuckle pattern of the imprinting carrier fabric 59, and by controlling dewatering, a pattern densified embryonic web may be formed in which web relatively high fiber density zones are juxtaposed the outwardly facing knuckles of

5 imprinting carrier fabric 59, and in which web the remaining portions which are unsupported and span the spaces between the knuckles have relatively low fiber density. Preferably, the unsupported spans are also acted on by sufficient differential fluid pressure while the web is at a sufficiently

10 low fiber consistency to sufficiently displace the unsupported spans into the interfilamentary spaces between the knuckles of the imprinting carrier fabric to obviate their being impregnated by impregnating means 65 although it is not intended to thereby limit the present invention. The embryonic

15 web is preferably predried to from about 30 to about 95 percent fiber consistency and more preferably to from about 60 to about 90 percent fiber consistency prior to being impregnated. Also, preferably the drying is sufficiently asymmetrical to dry the unsupported portions of the web

20 substantially more than the dense portions. This may be effected, for instance, by blow through predrying of the web while it is disposed on the imprinting carrier fabric of papermaking machine 30. This enhances the Z-direction penetration of the binder material through the thickness of the web and lessens the propensity of the binder material to migrate laterally in the X-Y directions into the low density portions of the web. Such X-Y migration into the low density portions of the web from the high density zones is further inhibited due to their relative capillary structures:

25

30 i.e., normally capillary flow is greater from low density to high density zones than from high density to low density zones. Moreover, with respect to latex type binder emulsions in particular, it is believed that the commencement of X-Y migration from relatively wet zones into dry areas acts to

35 dewater such emulsions and cause them to coagulate rather than migrate very far into the dry areas.

In addition to the impregnation of the high density zones which is effected as the web is carried on the imprinting carrier fabric 59 through the pressure biased impregnating means 65, Figure 5, the biasing also precipitates some compaction of and bonding within the high density zones of the web. Subsequently, as the high density zones of the web are again subjected to knuckle pressure between pressure roll 67 and Yankee dryer 75, the penetration of the binder is enhanced, and the degree of compaction and bonding within the high density zones is increased.

A number of handsheet examples as well as papermaking machine examples are described below. Briefly, the handsheet examples evidence the benefits of impregnating only dense zones of a pattern densified paper sheet in accordance with the present invention; and the papermaking machine examples evidence the benefit of subjecting impregnated high density zones to further mechanical pressure after the impregnating, and the benefits which may be derived from the present invention through the use of different impregnating materials.

20 HANDEEET EXAMPLE I

A pattern densified, one foot square (about 30 cm square) handsheet having a basis weight of about 16.5 pounds per 3000 square feet (about 27 grams per square meter) was formed from a fibrous furnish on a foraminous polyester fabric of the 5-shed satin weave shown in Figure 6 and having a 36-MD/32-CD filaments per inch (about 14-MD by 12.6-CD filaments per centimeter) mesh count. The furnish comprised about 60 percent by fiber weight of Tongacel (registered trademark of Louisiana Pacific Corporation) K 324N, a relatively low bond, long fiber, post bleach cold caustic extracted dissolving grade Northern Softwood Sulfite which is available from Louisiana Pacific Corporation, and about 40 percent by fiber weight of relatively long softwood fibers which were obtained from The Buckeye Cellulose Corporation under the designation Grand Prairie Prime, a Northern Softwood Kraft. After formation and draining, the

handsheet was further dewatered by pulling the fabric with the handsheet disposed thereon over a vacuum slot having 10 inches (about 25.4 centimeters) of mercury vacuum applied thereto. The handsheet was then dried on a can type dryer

5 while still disposed on the fabric and in its original relation thereto. The dried handsheet was then impregnated in its zones juxtaposed the top-surface-plane knuckles of the fabric by passing the fabric/sheet combination and a full-field gravure plate through the handsheet impregnating

10 apparatus 106 as indicated in the enlarged scale Figure 14 and as hereinbefore described. The latex binder comprised a 25 percent solids, self-crosslinking acrylic latex emulsion which was obtained from Rohm and Haas Company, Philadelphia, Pennsylvania, and which was designated TR-520. The latex

15 binder further comprised ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ), a latent acid catalyst, in the amount of about 0.5 percent by weight of latex solids; "Pluronic L-92" of about 1.0 percent by weight of latex solids, which is a nonionic surfactant sold by BASF Wyandotte Corporation, Parsippany, New Jersey, and

20 which was added to serve as a finished product wetting agent; ammonium hydroxide ( $\text{NH}_4\text{OH}$ ) in sufficient amount to raise the pH of the binder solution to about 5.0; Lithium Acetate ( $\text{CH}_3\text{CO}_2\text{Li}$ ) in the amount of 200 ppm Lithium based on the weight of latex solids to serve as a tracer to facilitate

25 analysis of samples to ascertain their latex content; and an anionic water soluble dye was added to allow visual inspection of the impregnation pattern. The gravure plate was etched to provide a full field of reservoirs which numbered about 22,500 reservoirs per square inch (about 3500 reservoirs per

30 square centimeter) and the corporate volume of the reservoirs was about 1.2 microliters per square centimeter of etched area.

#### HANDSHEET EXAMPLE 2

Handsheet Example 2 was a replicate of Handsheet Example

35 1 insofar as variables in the making thereof permitted.

HANDSHEET EXAMPLE 3

Handsheet Example 3 was prepared like Handsheet Examples 1 and 2 except for Number 3 the etched, full field gravure pattern comprised about 40,000 reservoirs per square inch 5 (about 6200 reservoirs per square centimeter), and the corporate volume of the reservoirs was about 2.2 microliters per square centimeter.

HANDSHEET EXAMPLE 4

Handsheet Example 4 was prepared like Handsheet Example 10 1 except that after it was dried on its forming fabric it was removed therefrom, rotated 90 degrees with respect thereto, and reassociated therewith with adhesive tape. Thus, the pattern of the zone densified handsheet was placed out of registration with the knuckle pattern of the fabric 15 prior to impregnation so that comparative data could be obtained with respect to out-of-registration impregnation (Handsheets Example 4) versus in-registration impregnation (Handsheets Examples 1, 2 and 3) of pattern densified fibrous webs.

HANDSHEET EXAMPLE 5

Handsheet Example 5 was prepared like Handsheet Example 4 except, prior to impregnation, the densified structure of the handsheet was placed out of registration with the knuckle pattern of the fabric by removing the handsheet from 25 the fabric and turning the handsheet over prior to reassociating it with the fabric with adhesive tape. This handsheet provided further out-of-registration-impregnation data which is tabulated along with the corresponding data from Handsheet Examples 1 through 4 in Table I.

HANDSHEET EXAMPLE 6

Whereas Handsheet Examples 1 through 5 were pattern densified during their formation on relatively coarse 36 X 32 mesh fabrics of the 5-shed satin weave shown in Figure 6, Handsheet Example 6 was formed with relatively uniform 35 density on a relatively fine mesh fabric having 110 X 95,

MD X CD filaments per inch (about 43 X 37, MD X CD filaments per centimeter), and woven with a 4-shed satin weave using a 1, 2, 3, 4 warp pick sequence. But for the different forming fabrics, Handsheet Example 6 was made and dried in the same 5 manner and of the same furnish as Handsheet Example 1. However, because the relatively fine mesh 4-shed satin weave fabric described above is much smoother than the relatively coarse 5-shed fabric shown in Figure 6, and because the fibers of the furnish were very long with respect to the 10 knuckle-to-knuckle span of the 110 X 95, 4-shed as compared to the coarser 36 X 32, 5-shed fabric, the handsheet formed on the 4-shed was relatively uniformly dense as compared to the pattern densified Handsheet Examples 1 through 5, inclusive. But, it is not intended to thereby imply that pattern densified 15 sheets cannot be formed on fine mesh fabrics such as the 4-shed satin weave described above. After being dried, Handsheet Example 6 was removed from the 110 X 95 forming fabric and taped onto a 36 X 32 mesh, 5-shed fabric identical to those used for Handsheet Examples 1 through 5 prior to 20 being impregnated by passing it through handsheet impregnating apparatus 106 in the manner indicated in Figure 14. The gravure plate and the latex binder composition were also the same for Handsheet Example 6 as for Handsheet Examples 1, 2, 4 and 5. Thus, Handsheet Example 6 was a pattern impregnated 25 sheet of relatively uniform density which yielded data which is also tabulated in Table 1 for conveniently comparing the pattern densified/pattern impregnated Handsheet Examples 1 through 3 embodying the present invention with the uniform density/pattern impregnated Handsheet Example 6.

30 Referring now to Table I, the Handsheet Examples 1 through 3 embodying the present invention clearly have superior (lower) bending modulus (i.e., greater flexibility) as compared to the out-of-registration impregnated/pattern densified Handsheet Examples 4 and 5, and as compared to the 35 pattern impregnated/uniform density Handsheet Example 6.

TABLE I

Handsheet Example Number	Binder on Product, Percent of Weight of Fibers	Area Covered, Percent	Total Dry	Total Wet	Wet Total	Bending Modulus, Kg/cm <sup>2</sup>
			Tensile Strength, g/inch	Tensile Strength, g/inch	Tensile, Percent of Dry Total Tensile	
5	1	7.82	39.1	986	414	42.0
	2	8.32	38.2	905	355	39.2
	3	10.56	51.6	1379	598	43.4
10	4	9.17	65.4	1093	415	38.0
	5	8.48	60.3	948	399	42.1
	6	9.68	58.4	1089	416	38.2

HANDSHEET EXAMPLES 7 AND 8

Two additional Handsheet Examples embodying the present invention were prepared in the same manner and with the same furnish as Handsheet Examples 1 through 3 except the gravure plates were engraved to provide different levels of binder addition. Pertinent data from these two examples are tabulated in Table II; in particular, comparative dry strength and wet strength data which evidences that embodiments of the present invention have greater strength derived from a given amount of binder than the non-pattern densified Handsheet Example 9 described next.

HANDSHEET EXAMPLE 9

This handsheet was of relatively uniform density and was formed, dewatered and dried substantially identically to Handsheet Example 6 using the same furnish as for Handsheet Examples 1 through 8. However, whereas Handsheet Example 6 was impregnated by a full-field gravure plate while backed by a 36 X 32 5-shed fabric in the manner shown in Figure 14, Handsheet Example 9 was impregnated in the manner shown in Figure 15; that is, not backed by a fabric. In this instance, the gravure plate 115 was prepared with a pattern identical in size and geometry to the top-surface-plane knuckles of a 36 X 32 5-shed fabric, Figure 6. The gravure pattern comprised about 22,500 reservoirs per square inch of reservoirs.

(about 3,500 reservoirs per square centimeter of reservoirs) and was derived from a 150 X 150 lines per inch (about 59 X 59 lines per centimeter) screen which was superimposed on a knuckle-pattern print made from the 36 X 32 5-shed fabric

5 59, Figure 6, to make a negative which was then used in producing an acid etched gravure plate. Therefore, the uniform density Handsheet Example 9 was pattern impregnated in the same pattern as Handsheet Examples 7 and 8 embodying the present invention. However, whereas Handsheet Examples  
 10 7 and 8 were pattern densified prior to their being impregnated in their dense zones, Handsheet Example 9 was of uniform density; i.e., having no dense zones.

TABLE II

15 Handsheet Example	Basis Weight lbs/3000 sq.ft.	Binder Percent of Weight of Fibers	Total Dry Tensile Strength, g/inch	Total Wet Tensile Strength, g/inch	Wet Total Tensile, Percent of Dry Tensile
			703	258	36.7
7	16.2	4.64	703	258	36.7
20 8	16.0	5.40	834	317	38.0
9	15.4	5.02	540	175	31.6

Another benefit which may be derived from the present invention is precipitated by the application of pressure to the binder impregnated dense zones as, referring to Figure 25, the pattern densified embryonic web 20e (backed by fabric 59) passes through the pressure biased nip intermediate pressure roll 67 and Yankee dryer 75 prior to the final drying and creping of the web. The following example, Example 10, illustrates this.

30

EXAMPLE 10

Basically, a papermaking machine of the general configuration as papermaking machine 30, Figure 5, was run to produce two families of samples during which run: the percent of latex solids in the binder emulsion in reservoir 35 85 was incremented from 10 to 25 and then to 40 percent; the after predryer (APD) fiber consistency was varied from about

68 percent to about 91 percent; and samples were taken from adjacent the doctor blade 78 which samples had about zero crepe, and from intermediate roll 66 and pressure roll 67. In the data tabulated in Table IIIa and IIIb, the former samples are designated Pressed Samples, and the latter samples are designated Unpressed Samples; and pairs of samples are designated by pair numbers which pairs each comprise a Pressed Sample and an Unpressed Sample.

10

TABLE IIIa

EXAMPLE 10

POST IMPREGNATION PRESSING OF DENSE ZONES  
PRESSED SAMPLES VS. UNPRESSED SAMPLES

15	Sample	Percent Solids In Latex	APD Fiber Consistency, Percent	Total Wet Tensile Strength, % Of Total Dry Tensile Strength		Ratio, Pressed To Unpressed (Ratio of Column 4 to Column 5)
				Pressed	Unpressed	
20	1	10	76.0	28.0	28.3	.99
	2	10	88.9	27.6	26.1	1.06
	3	25	67.6	39.7	32.4	1.23
	4	25	88.7	40.2	27.9	1.44
	5	40	67.6	39.0	31.4	1.24
	6	40	90.9	31.4	21.5	1.46

25

TABLE IIIb

EXAMPLE 10

POST IMPREGNATION PRESSING OF DENSE ZONES  
PRESSED SAMPLES VS. UNPRESSED SAMPLES

30	Pair No.	Wet Tensile Strength, g/inch					
		Pressed			Unpressed		
		MD	CD	Total	MD	CD	Total
	1	46	39	85	83	50	133
	2	74	44	118	66	41	107
	3	115	80	195	99	63	162
35	4	111	83	194	76	44	120
	5	95	72	167	85	60	145
	6	43	54	97	56	41	97

The samples of Example 10 were made on a papermaking machine of the general geometry of machine 30, Figure 5, using the 60 percent Tongacel/40 percent Grand Prairie Prime (low bond/kraft softwood fibers, respectively), long fiber furnish as used to make Handsheet Examples 1 through 9 described above. This furnish was chosen to produce, if not impregnated in accordance with the present invention, a weak web with less than 150 grams per inch total tensile strength (the sum of the machine direction tensile strength plus the cross machine direction strength). A 0.12 percent fiber consistency pulp slurry of this furnish was distributed on a Fourdrinier wire 33 of a 4-shed satin weave having a 78 X 60, MD X CD filament mesh count per inch (about 31 by 24 filaments per centimeter). Dewatering was progressively effected while the web was being forwarded on the 78 X 60 Fourdrinier wire, and then on intermediate carrier wire 51 of the same mesh, weave, and material as the Fourdrinier wire to increase the fiber consistency of the web to about 22 percent prior to being transferred to the imprinting carrier fabric 59 which was a 5-shed satin weave of the type shown in Figure 6 and having 31 X 25, MD X CD filaments per inch (about 12 X 10 filaments per centimeter). Further dewatering was precipitated by vacuum transfer box 61 and the triple vacuum box 62 to provide a fiber consistency of about 32 percent. The result of vacuum transferring from the 78 X 60 intermediate carrier fabric 51 to the 31 X 25 imprinting carrier fabric 59 and the vacuum dewatering thereon caused the web to become pattern densified thereby completing the formation of the pattern densified web: discrete spaced dense zones juxtaposed top-surface-plane knuckles of imprinting carrier fabric 59, and relatively low density spans or portions between those knuckles. These conditions also caused the unsupported portions of the web to be displaced by the vacuum induced differential fluid (air) pressure into the interfilamentary voids of fabric 59. The web was then predried by blow through predryer 64 to an APD fiber consistency in the range stated above: about 68 percent to about 91 percent. The web, still disposed on fabric 59 then was forwarded thereon through a full-field

pattern, pressure biased gravure impregnating means of the type described hereinbefore which caused the dense zones of the web to be pressed against the gravure cylinder 81 and thereby become impregnated; however, the low density span 5 portions were not so impregnated by virtue of having been sufficiently displaced into the interfilamentary spaces of fabric 59 to substantially obviate their being impregnated by the impregnating means. Additionally, binder impregnation of the low density span portions was substantially obviated 10 by not pressing them against the rotogravure cylinder 81. Rotogravure cylinder 81 was engraved with a full-field pattern of reservoirs (cells) numbering about 3500 per square centimeter and having a total volume of about 1.4 15 microliters per square centimeter.

15 The binder material used to impregnate the samples of Example 10 was the same latex emulsion as for the hereinbefore described handsheets except: the percent solids was incremented from 10 to 25 and then to 40 percent; and very low levels of commercial defoamers "(Foammaster 160L" and 20 "Colloid 694)" were added to suppress foaming of the latex emulsion 25 in reservoir 85 as cylinder 81 rotated therethrough and the excess latex was doctored therefrom. "Foammaster 160L" was obtained from Diamond Shamrock Corporation, Cleveland, Ohio; and "Colloid 694" was obtained from Colloids, Inc., 25 Newark, New Jersey.

Further with respect to Example 10, backing roll 82, Figure 5, was an 80 Shore A Durometer rubber covered roll; and pressure roll 67 was an 85 Shore A Durometer rubber covered roll. Roll 82 was biased towards cylinder 81 with a 30 force of about 20 pounds per lineal inch (about 3.5 kilograms per lineal centimeter); and pressure roll 67 was biased towards Yankee cylinder 75 at about 440 pounds per lineal inch (about 78 kilograms per lineal centimeter). The creping adhesive which was applied to Yankee dryer 75 via spray 35 applicators 77 to enable creping was "Gelvatol 20-90";\* a polyvinyl alcohol/acetate manufactured by Monsanto Co., St. Louis, Missouri. After being creped from the Yankee dryer

\* Trademark

\*\* Trademark

\*\*\* Trademark

75 by doctor blade 78, the paper web from which the pressed samples were taken was reeled at the same speed as the Yankee; thus the samples exhibited virtually zero residual crepe so that residual crepe would not be a substantial difference between the pressed samples and the unpressed samples which were obtained as follows. The unpressed samples of Example 10 were obtained by pressing a sheet width, adhesive coated, rotatably mounted spool against the web on fabric 59 running from roll 66 towards pressure roll 67 to accumulate sufficient web on the spool to run samples thereof which were not adulterated by the adhesive on the spool. The samples were tested to obtain the Tables IIIa and IIIb data after being cured for about 5 minutes at about 300°F. (about 150°C.).

Generally, the data in Tables IIIa and IIIb indicate that post-impregnation pressing as described hereinbefore precipitates improved wet tensile strength; and greater wet tensile strength for a 25 percent level of solids in a latex binder emulsion than for either a 10 percent or 40 percent level of solids. Furthermore, post-impregnation pressing also generally improves the ratio of total wet strength to total dry strength of the paper which is generally regarded as a performance parameter for paper towels and the like.

Three more papermaking experiments which are designated and described below as Examples 11, 12, and 13 were conducted to produce papers embodying the present invention: that is, pattern densified papers having discrete, spaced, binder impregnated zones of high fiber density and otherwise being substantially low bond, high bulk, unimpregnated structures. Data from these examples are tabulated in Table IV.

TABLE IV

		EXAMPLE 11 2-Ply Paper Towel	EXAMPLE 12 2-Ply Paper Towel	EXAMPLE 13 3-Layer Toilet Tissue
5	Basis Weight: pounds per 3000 sq.ft. (grams per square meter)	34.2 (55.8)	39.2 (63.9)	16.8 (27.4)
	Caliper: mils (mm)	33.1 (0.83)	30.0 (0.76)	10.7 (0.27)
10	Dry MD Tensile Strength: grams/inch (grams/centimeter)	465 (183)	924 (364)	196 (77)
	Dry CD Tensile Strength: grams/inch (grams/centimeter)	346 (136)	559 (220)	144 (57)
	Wet CD Tensile Strength: grams/inch (grams/centimeter)	157 (62)	176 (69)	Not Measured
15	Wet/Dry CD Tensile Strength	47%	31%	
	Wet Tear Strength: grams	56.0	53.0	Not Measured
	Stretch MD	19%	35%	23%
	Stretch CD	11%	9%	7%
20	Softness: Subjective Panel Score Units, Example Versus a Contemporary Paper Product Of Comparable Basis Weight	+1.7	+1.0	+1.7
	Spill Wipe-Up: Subjective Panel Score Units, Example Versus a Contemporary Paper Product of Comparable Basis Weight	-0.4	+0.9	Not Measured
	Binder Content, Estimated As Percent Of Fiber Weight	6%	2%	2.4%
30	Binder: Type	Latex Emulsion	Polymeric Solution	Latex Emulsion
	Concentration	40% Solids	10% Solution	5% Solids

Briefly, Examples 11 and 12 were made using low bond Tongacel, described hereinbefore, in the furnishes to provide low bond webs, and the process conditions were so controlled that the webs were pattern densified when fully formed, and 5 then impregnated with binder material in their dense zones to enhance both their wet and dry strengths: a latex emulsion binder for Example 11 and a polymeric solution type binder for Example 12.

More specifically, Example 11 was made from the same 10 60% Tongacel/40% Northern Softwood Kraft and in the same manner as Example 10 except for a relatively constant APD fiber consistency of 78 percent; and except for the latex binder having 40 percent solids and containing no lithium tracer or dye. After the paper web was creped and doctored 15 from the Yankee dryer, Example 11 was calendered by a rubber/steel calender roll pair at about 58 pounds per square inch (about 400 kPa) and reeled at a speed of 75 percent of the Yankee to provide a relatively high degree of residual crepe. The reels of paper were then combined into 20 2-ply paper towels with the non-Yankee-contacting sides of both plies in face-to-face relation, and embossed and adhesively secured together as taught by U.S. Patent No. 3,414,459 which issued December 3, 1968 to E. R. Wells, and shown in sectional-view Figure 6 thereof. The combined 25 product was cured at 350°F. for about 3 seconds, reeled, and then tested. The data are tabulated on Table IV. These paper towels exhibited high strength and an extraordinary ratio of wet/dry CD tensile strength as compared to a variety of contemporary paper towels yet scored substantially higher 30 in subjectively perceived softness. Also, the data evidences that the converting process removed a substantial portion of the residual crepe in the paper.

Example 12 was also made on a papermaking machine of the same general geometry as machine 30, Figure 5, except, a 35 three chamber divided headbox (not shown) was used to deliver two types of fiber slurries onto the Fourdrinier wire 33 in superposed relation. The first-down slurry juxtaposed the

Fourdrinier wire was identical to the low bonding pulp slurry of "Tongacel" / Northern Softwood Kraft which was used to make Examples 10 and 11, and was issued from the bottom chamber of the headbox at a fiber consistency of about 0.20 percent. Northern Softwood Kraft slurries were simultaneously issued from both the center and top headbox chambers at a fiber consistency of about 0.12 percent. The Fourdrinier wire 33, and intermediate carrier fabric 51 were the same 78 X 60 mesh and weave, respectively, as used for Examples 10 and 11. However, the imprinting carrier fabric 59 was the same 36 X 32, 5-shed mesh and weave as used for Handsheet Example 1. Fiber consistency was 13 percent prior to transfer to fabric 59; 29 percent before predryer (BPD); and about 96 percent APD.

15 The binder used for Example 12 was a 10 percent solution of "Parez 631 NC,"\* a papermaking wet strength resin sold by American Cyanamid Company, Wayne, New Jersey. This is believed to be a reaction product of glyoxal with a copolymer of dialkyl dimethyl ammonium chloride and acrylamide.

20 The rotogravure cylinder used for Example 12 was the same as for Examples 10 and 11; and the web was finished, creped, calendered, reeled, converted to 2-ply paper towels, and tested to the same degree and in the same manner as Example 11 except both plies were oriented to place their 25 low bond layers on the outside of the structure. The resulting data are tabulated in Table IV.

Example 13 was formed as a 3-layer structure using the 3-compartment headbox described above and in the same general manner in the same papermaking machine as Example 12. The 30 three layers consisted of Champion Eucalyptus on the top and bottom and Grand Prairie Prime Northern Softwood Kraft in the middle. The Champion Eucalyptus was obtained from Champion International Corporation, Stamford, Connecticut. All pulps were at 0.13 percent consistency when distributed 35 at three equal basis weights to produce a web on the machine of 17.7 pounds per 3000 square feet (about 28.9 grams per square meter) basis weight. The kraft layer was made from

\* Trademark

low bonding pulp furnish which had "Quaker 2003"\*(a stearyl imidazoline made by Quaker Chemical Company, Conshohocken, Pennsylvania) added at a level of about 0.25 weight percent of the kraft. The web was initially formed on the same 78 X 5 60 Fourdrinier wire used for Examples 10, 11, and 12, and subsequently transferred and dewatered as generally described with respect to those Examples. The imprinting carrier fabric was a 3-shed semi-twill having a mesh count of 31 X 25, MD X CD filaments/inch, and was treated to provide 10. imprinting knuckles as described in U.S. Patent No. 3,905,863 which issued September 16, 1975 to P. G. Ayers. The net result of vacuum transferring from a 78 X 60 intermediate fabric to a 31 X 25 imprinting carrier fabric and subsequent dewatering was to produce a web on the 31 X 25 mesh imprinting 15 carrier fabric of non-uniform density having low density portions juxtaposed the voids in the fabric, and high density zones juxtaposed the fabric knuckles.

The latex binder used was "Airflex 402"\*\* which was obtained from Air Products And Chemicals Inc., Allentown, Pennsylvania; 20 a dry strength vinyl-acetate ethylene emulsion. This was adjusted to have a 5% level of solids, and applied by the same rotogravure cylinder of Example 10. The impregnated web, still disposed on and in register with the 31 X 25 imprinting carrier fabric, was then pressed at about 440 pli (about 78 kilograms per lineal centimeter) against the Yankee dryer, using a rubber covered pressure roll with a Shore A Durometer hardness of 85 loaded against the dryer to imprint the knuckle pattern of the fabric into the web and thereby compact the dense zones thereof. "Gelvatol 20-90" 25 30 polyvinyl alcohol/acetate manufactured by Monsanto was applied to the Yankee dryer upstream from the pressure roll to adhere the web to the Yankee and allow creping at the doctor blade after the web was dried. The web was then run through a rubber roll/steel roll papermaking calendering nip 35 at a light load and wound up on a reel at 82% of the Yankee speed. The reels of paper thus obtained were rewound and slit into standard toilet tissue rolls and tested. The test data are tabulated in Table IV.

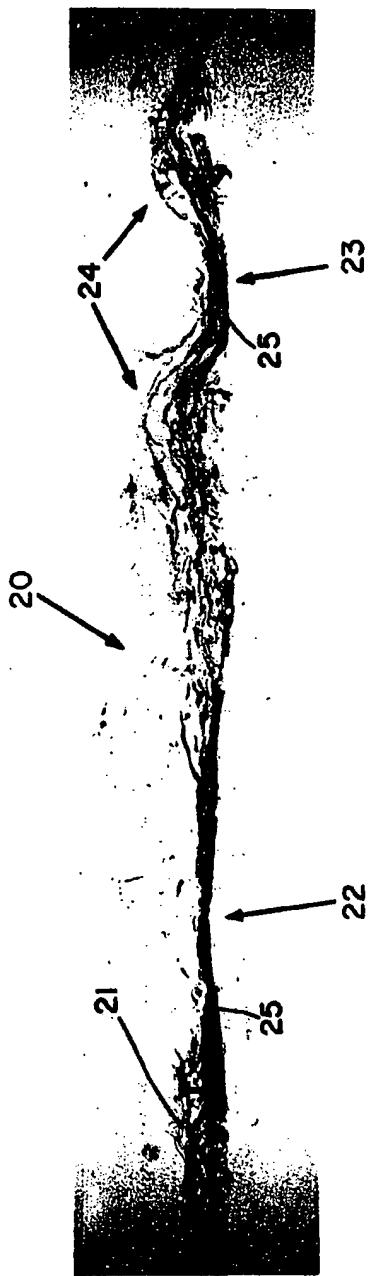
\* Trademark  
\*\* Trademark

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit 5 and scope of the invention. Therefore, it is intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

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11-1

Fig. 1



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1155007

11-2

Fig. 2

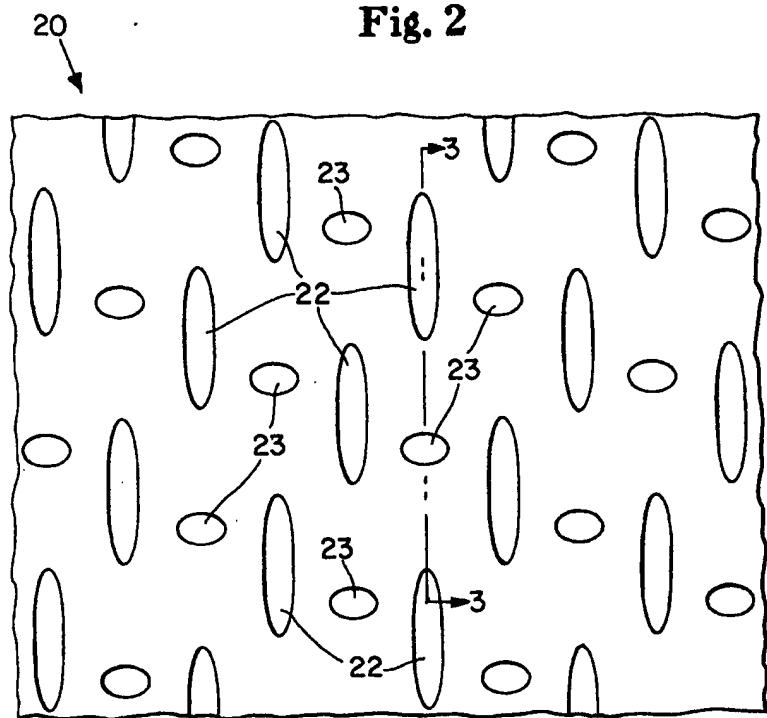


Fig. 3

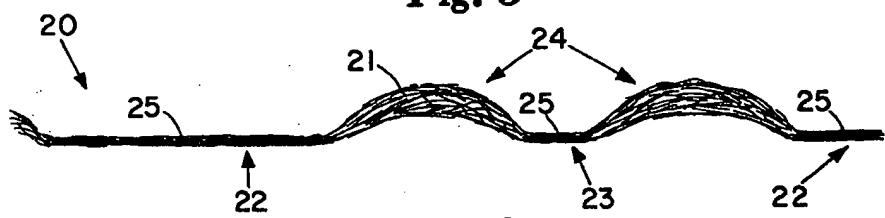
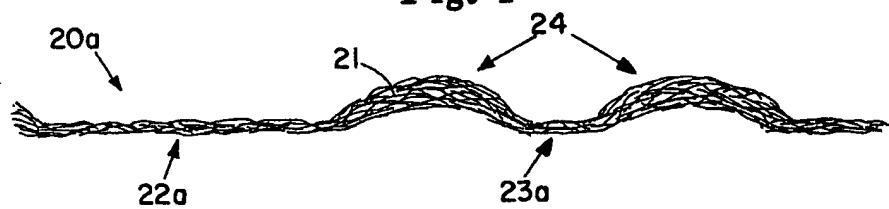


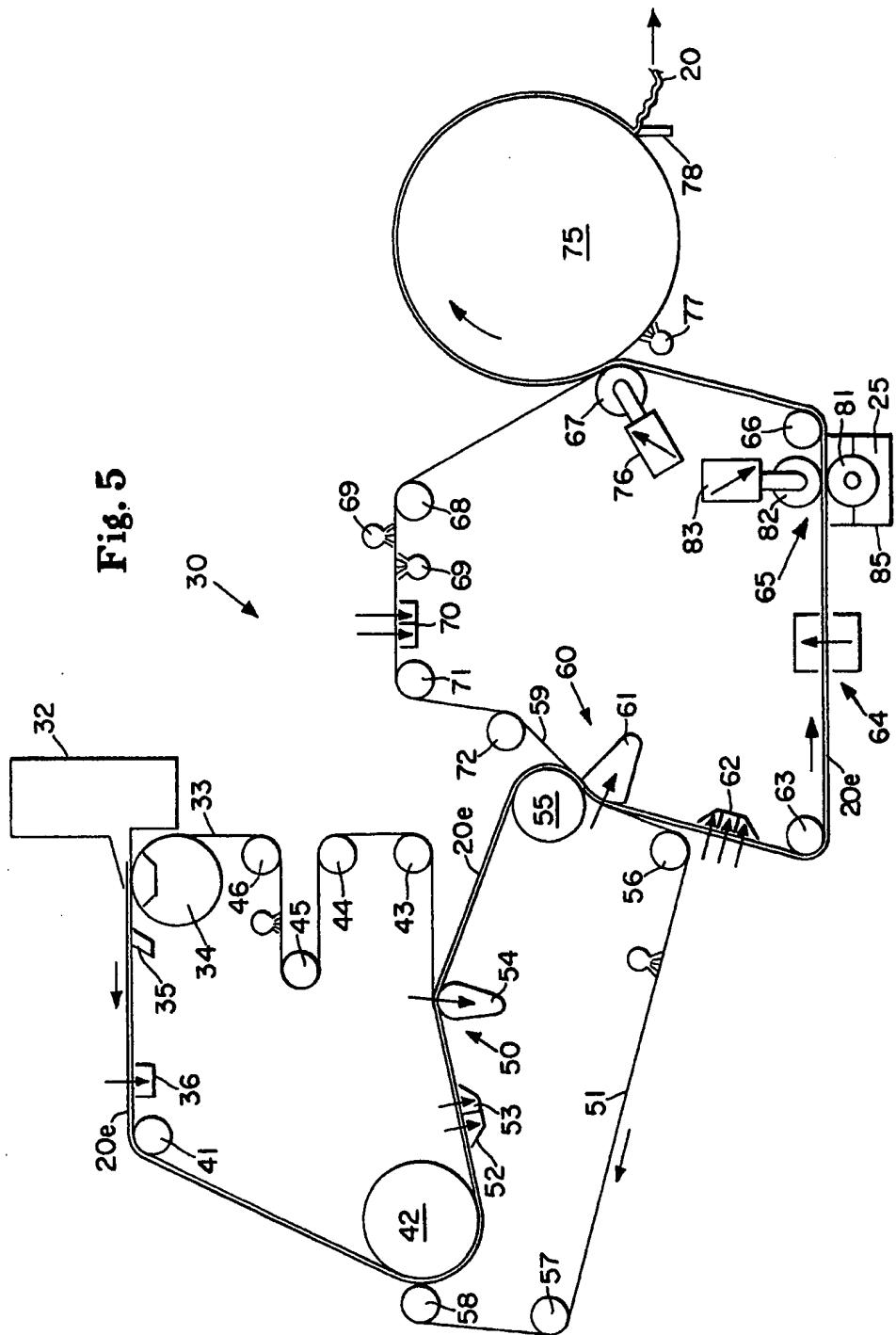
Fig. 4



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1155007

11-3

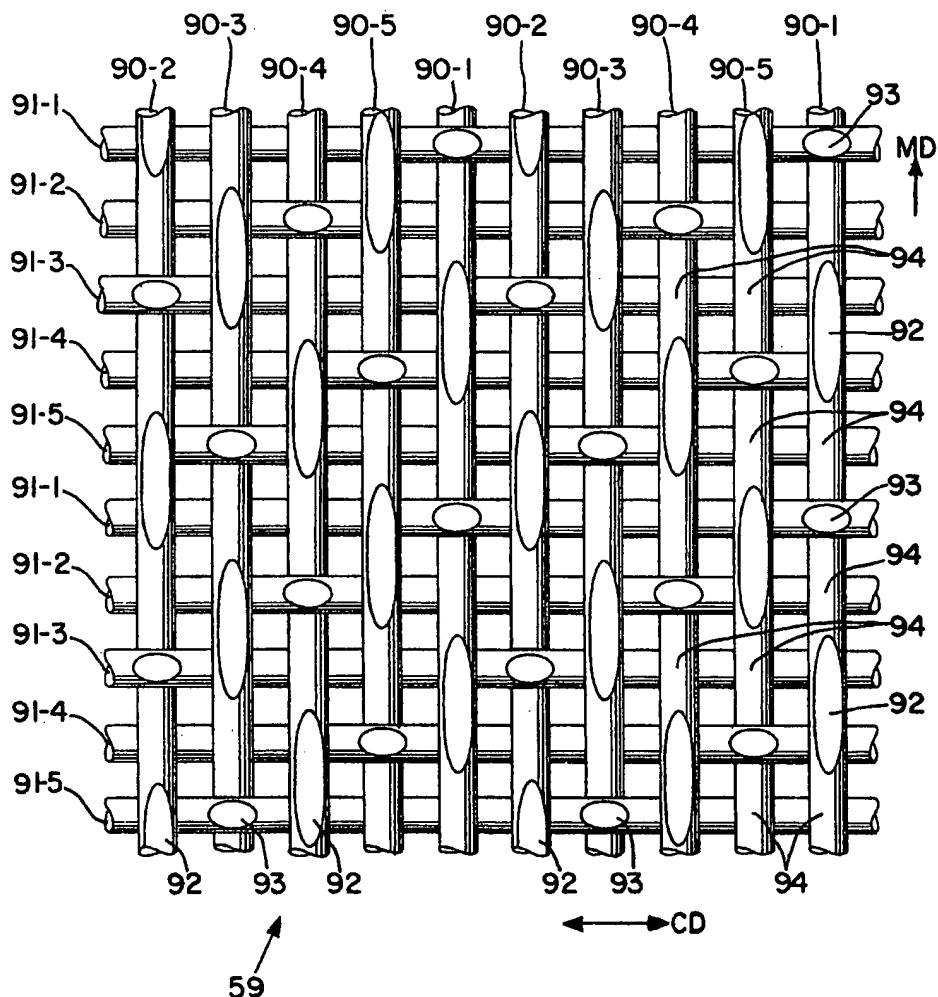


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1155007

11-4

Fig. 6



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1155007

11-5

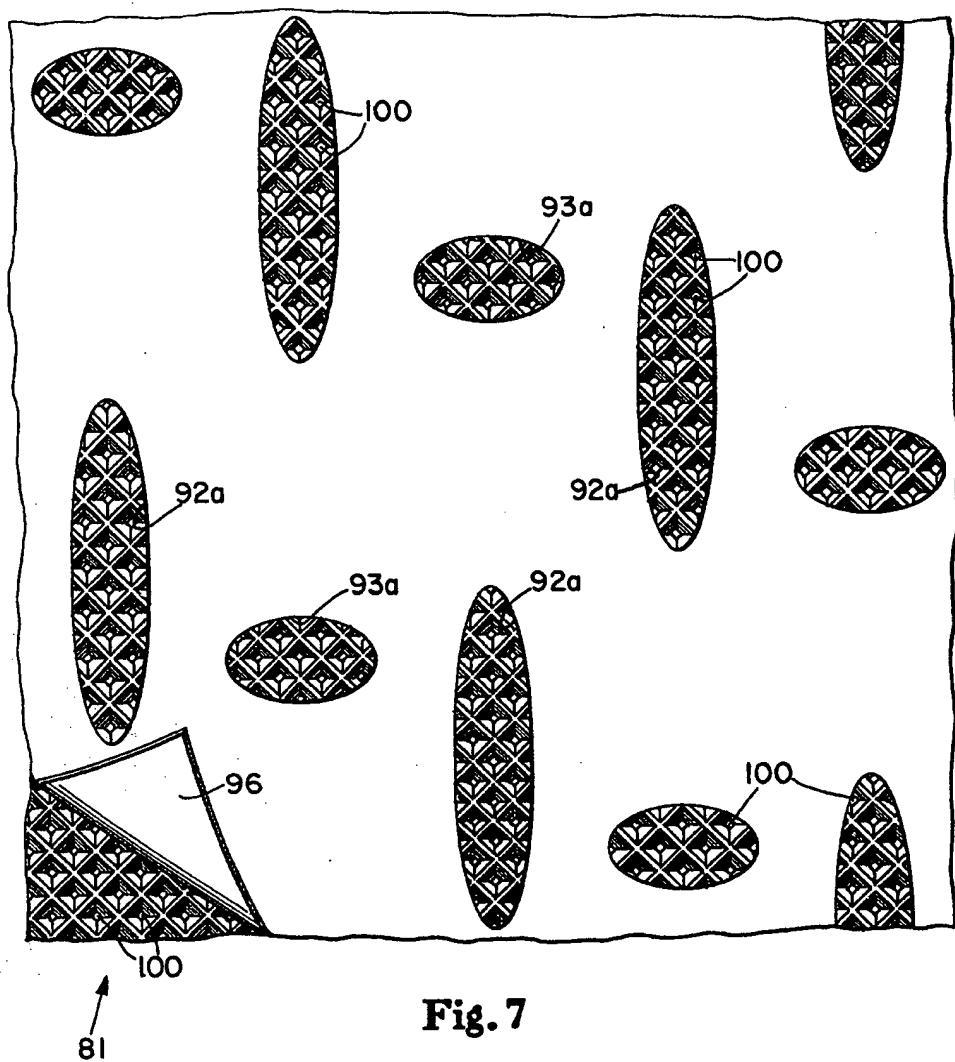


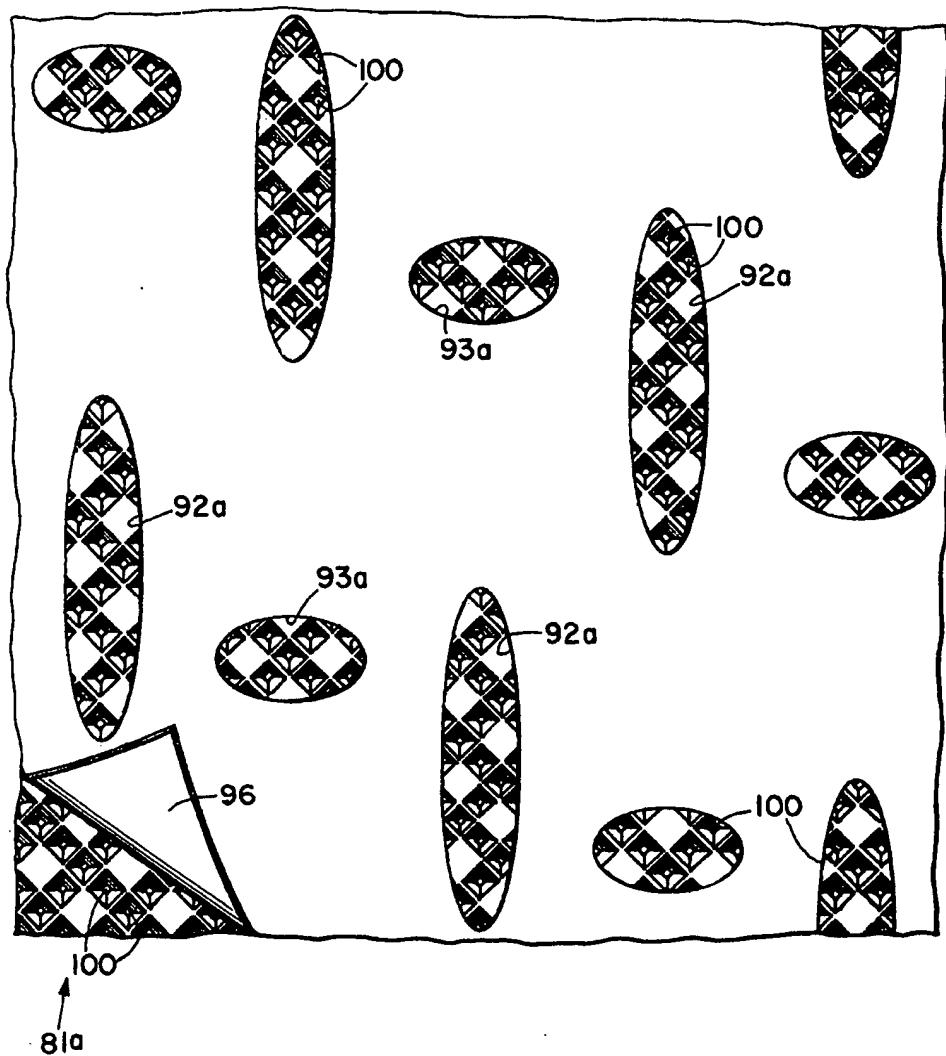
Fig. 7

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1155007

11-6

Fig. 8

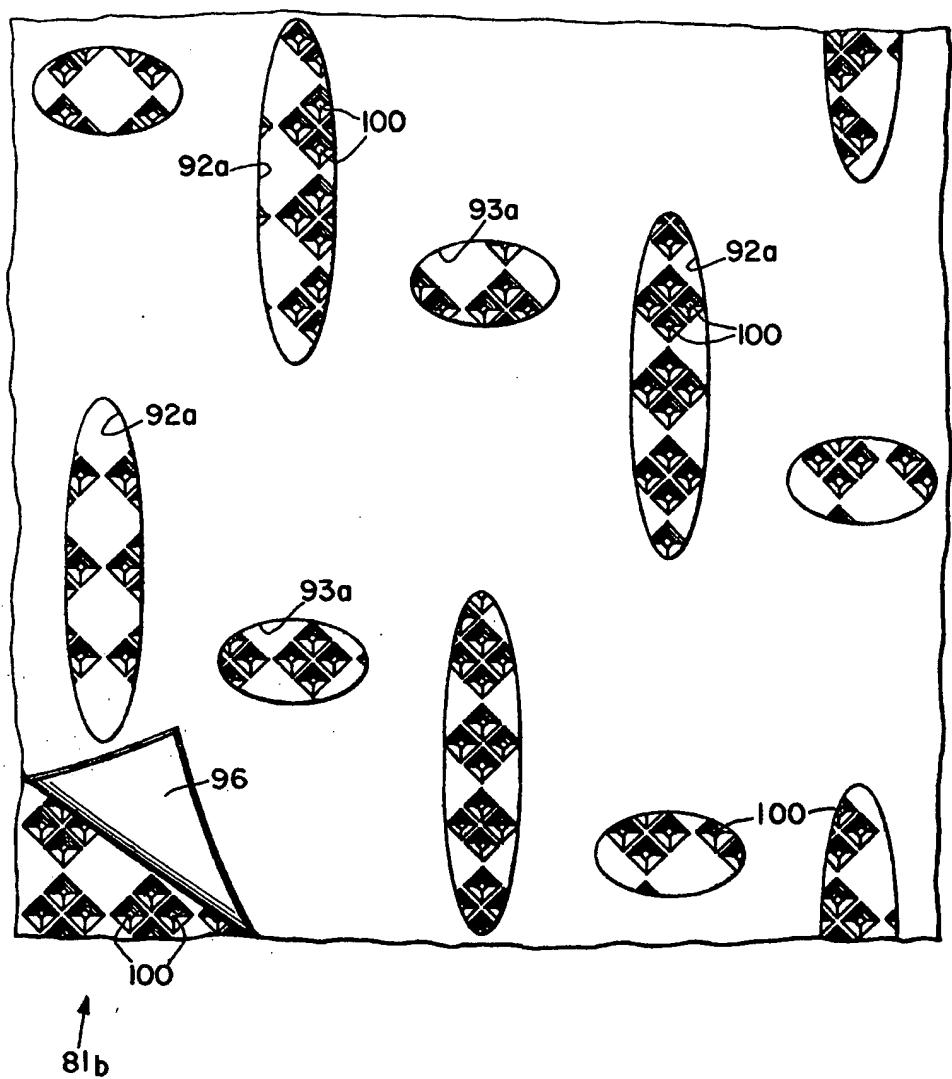


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1155007

11-7

Fig. 9

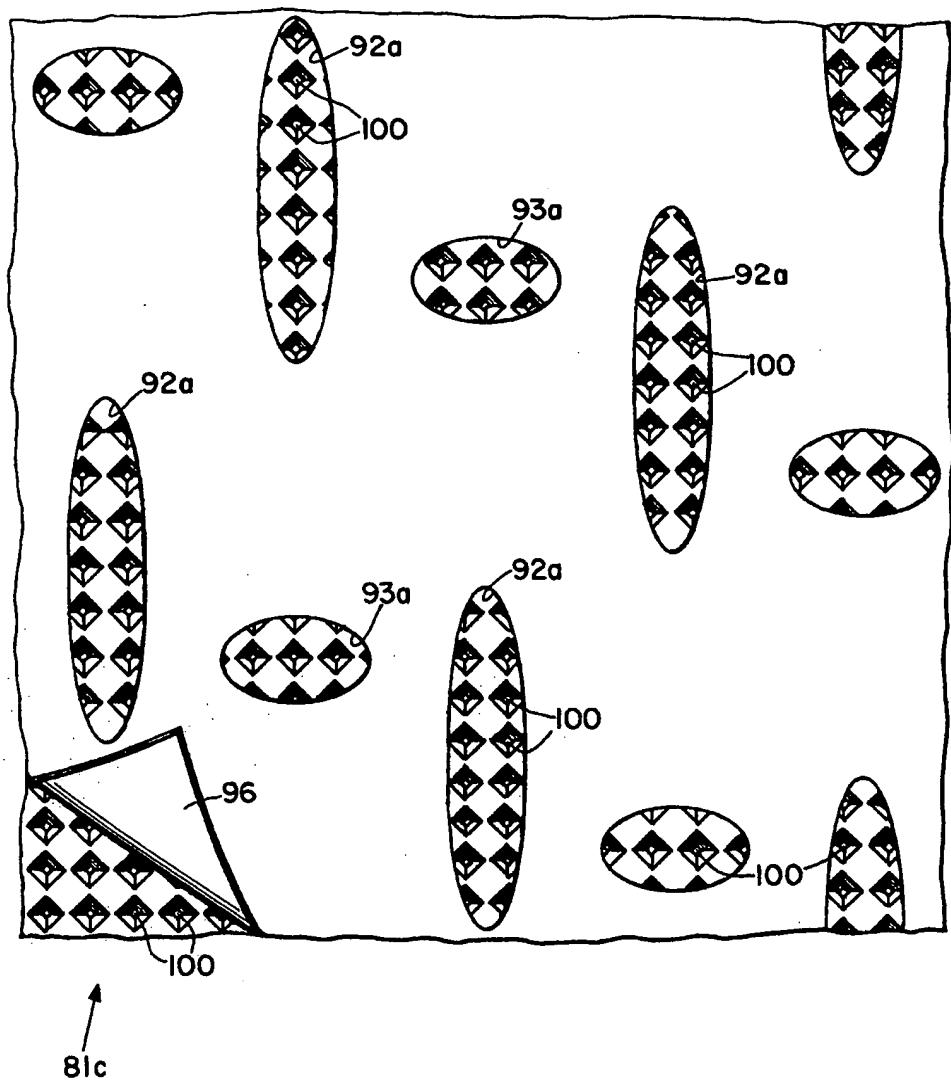


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1155007

11-8

Fig. 10

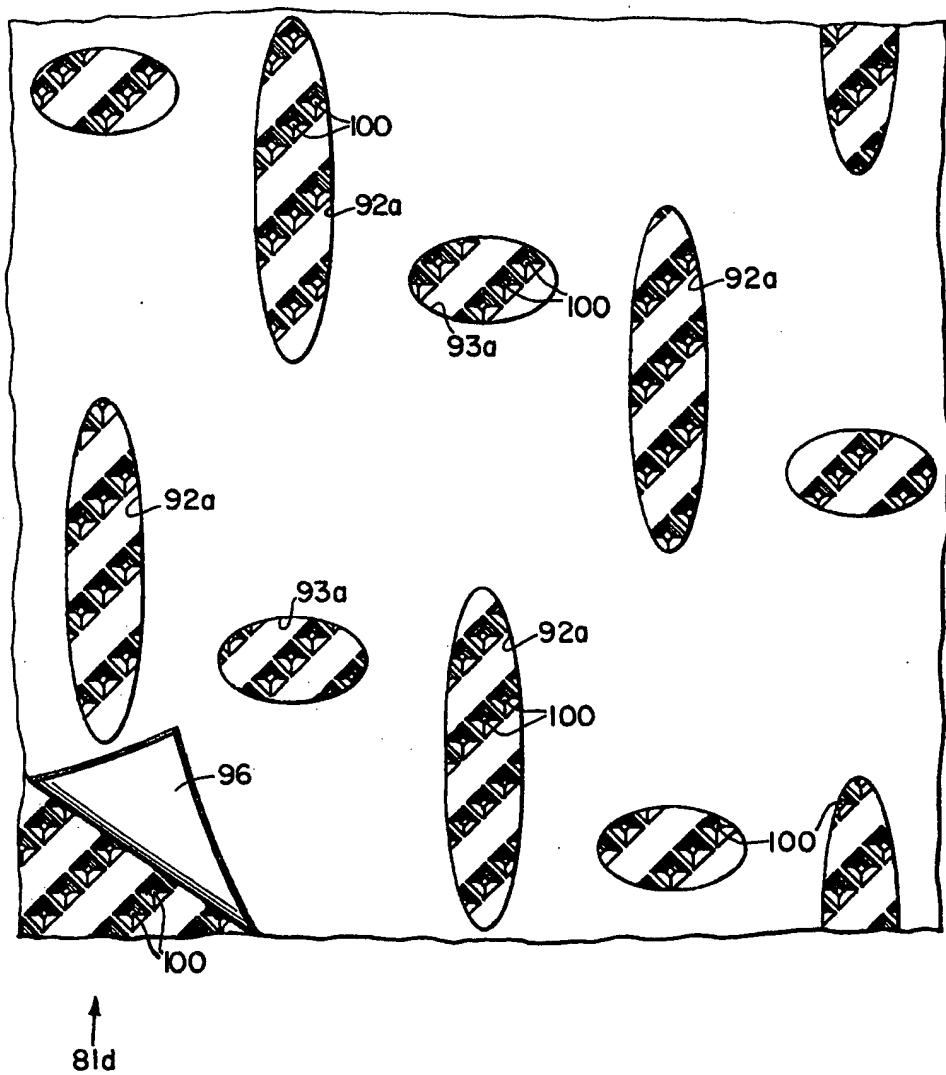


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1155007

11-9

Fig. 11

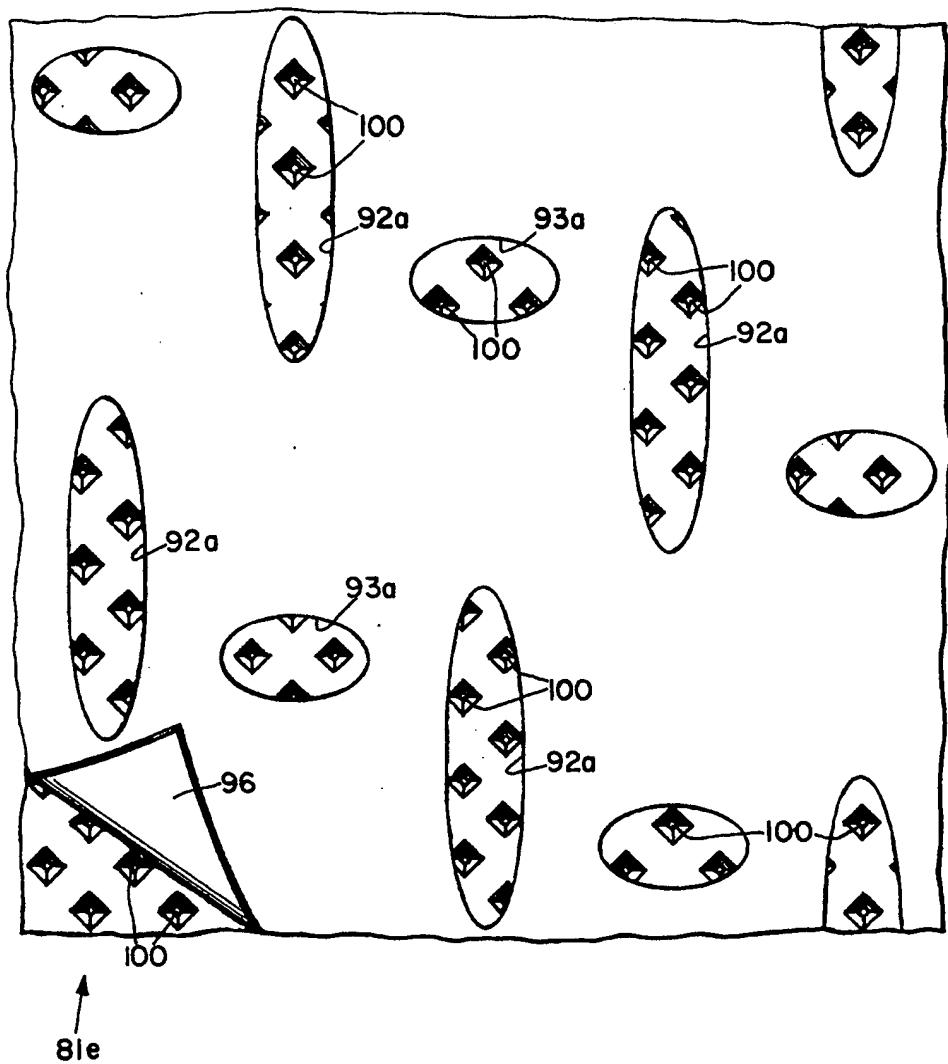


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1155007

11-10

Fig. 12



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1155007

11-11

Fig. 13

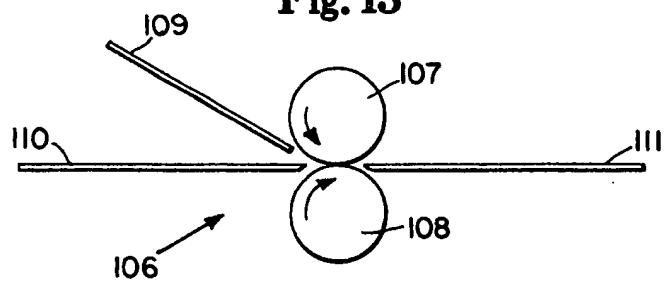


Fig. 14

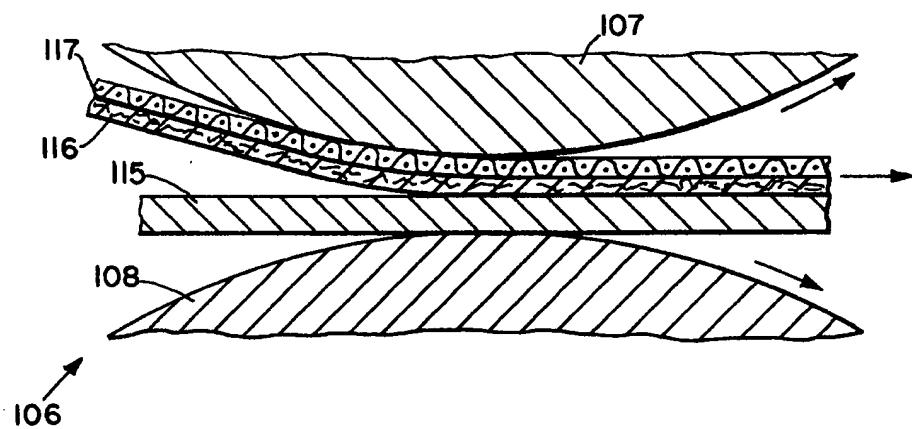
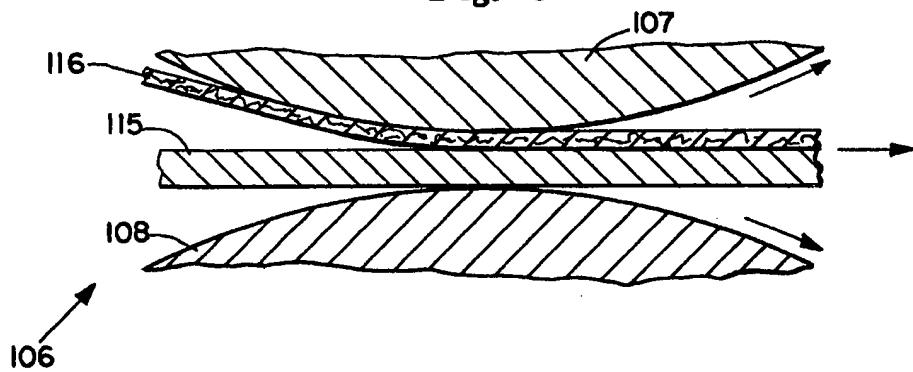


Fig. 15



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